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ORIGINAL PAPER

Revealed comparative advantage and the alternatives as measures of international specialization

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Abstract This paper provides an analysis of Balassa's 'revealed comparative advantage' (RCA). It shows that when using RCA, it should be adjusted such that it becomes symmetric around its neutral value. The proposed adjusted index is called 'revealed symmetric comparative advantage' (RSCA). The theoretical discussion focuses on the properties of RSCA and empirical evidence, based on the Jarque–Bera test for normality of the regression error terms, using both the RCA and RSCA indices. We compare RSCA to other measures of international trade specialization including the Michaely index, the Contribution to Trade Balance, Chi Square, and Bowen's Net Trade Index. The result of the analysis is that RSCA—on balance—is the best measure of comparative advantage.

Keywords Revealed comparative advantage · International specialization

JEL Classification C43 · F14

1 Introduction

Half a century ago, Bela Balassa's seminal paper (1965) proposed the first use of 'Revealed Comparative Advantage' (RCA). Since then the measure has been

This paper draws on Laursen (2000a). The author thanks Mario Pianta for the suggestion to write a paper on this topic, and two reviewers for this journal for excellent comments and suggestions for improvements. The usual caveats apply.

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applied in numerous reports (e.g. UNIDO 1986; World Bank 1994; OECD 2011) and academic publications (e.g., Aquino 1981; Crafts and Thomas 1986; van Hulst et al. 1991; De Benedictis et al. 2008; Amighini et al. 2011), to measure international trade specialization, to gauge technological specialization based on patent data (e.g., Soete and Wyatt 1983; Cantwell 1995; D'Agostino et al. 2013; Liegsalz and Wagner 2013), and to capture production specialization (e.g., Iapadre 2001; Laursen and Salter 2005). However, although previous work has examined the properties of this measure in detail (e.g., Yeats 1985; Vollrath 1991; Hinloopen and van Marrewijk 2008), not enough is known about the effects of it being asymmetric around its neutral value, and moreover, it is not clear how the Balassa index compares to other measures of international specialization. The present paper examines these issues from both theoretical and empirical perspectives.

These aspects are important, not least because findings related to potential biases would have (potentially serious) implications for a wide range of topics in economics and social science more widely, which involve econometric analysis that uses international specialization measures as central variables—including analyses that employ RCA or some version of it. Those topics involve, among others, analysis of the factors affecting the direction of international trade (Laursen and Drejer 1999) or technological specialization (Malerba and Montobbio 2003); level of trade (Amiti 1999) or technology specialization (Archibugi and Pianta 1994); and studies linking international trade (Dalum et al. 1999; Laursen 2000a) or technological specialization (Meliciani 2002) to economic growth. Recently, an important literature on the link between the complexity of export structure and economic development (see for instance, Hidalgo et al. 2007; Hausmann and Hidalgo 2011) has used RCA as a central component in the related empirical analysis.

The paper is organized as follows. First, in Sect. 2 we briefly describe the sectors in which countries are specialized using the RCA which provides as a basis for the subsequent analysis. Section 3 argues that when using RCA in econometric analysis, it should always be adjusted so that it becomes symmetric around its neutral value. Section 4 compares the adjusted RCA (i.e. the revealed symmetric comparative advantage or RSCA) to other measures of international trade specialization used in the literature such as the Contribution to Trade Balance, the Michaely index, the Chi Square measure, and Bowen's Net Trade Index. Section 5 concludes.

2 Countries' trade specialization

2.1 A first look at specialization patterns

The concept of specialization implies a strong focus on one narrow area of activity and a less intense focus on others. In the context of international export specialization, RCA is a relative measure indicating a strong focus on some sectors but less on others. Accordingly, Revealed Comparative Advantage (Balassa 1965) can be defined as:

$$RCA = \frac{X_{ij}/\sum_i X_{ij}}{\sum_i X_{ij}/\sum_i \sum_j X_{ij}} \quad (1)$$

The numerator represents the percentage share of a given sector in national exports—X_{ij} are exports to sector i from country j. The denominator represents (for instance) the percentage share of a given sector in OECD exports. Thus, the RCA index provides a comparison of the national export structure (the numerator) with the OECD export structure (the denominator). If the RCA of a given sector in a given country equals 1, the percentage share of that sector is the same as the OECD average. If the RCA is above 1 the country is said to be specialized in that sector and if the RCA is below 1 it is said not to be specialized (or 'under-specialized'). Since the RCA results in an output which cannot be compared on both sides of 1 (its neutral value)[1], we propose making the index symmetric, as (RCA − 1)/(RCA + 1); thus this measure ranges from −1 to +1. We call this measure Revealed Symmetric Comparative Advantage (RSCA).

Note that the RCA/RSCA is a measure of international specialization and not of international competitiveness or any other concept indicating performance. RCA has sometimes been applied in misleading ways (see e.g., Fagerberg 1997). RCA/RSCA is a measure of relative not absolute strength. The values of the measure imply that regardless of how poorly (or strongly) a country is performing, by definition the country will be specialized in something, and therefore will always have high values of RCA/RSCA for some sectors of the economy and low values for other sectors.

Table 1 presents specialization figures for 27 OECD countries in 2006, based on calculations on the OECD STAN database (ISIC Rev. 3 version of STAN, downloaded from stats.oecd.org in September 2014). Table 1 shows that among OECD catching-up countries Korea is specialized in (among other things) office machines and computers; communications and semiconductors; and shipbuilding. Areas of under-specialization include food, drink and tobacco; wood, cork and furniture; and pharmaceuticals. Among small high-income countries Denmark is specialized in food, drink and tobacco; textiles, footwear and leather; wood, cork and furniture; and pharmaceuticals. Areas of relative weakness include motor vehicles; and office machinery. Among the large high-income countries, Germany has relative strength in non-electrical machinery and in motor vehicles, and relative weakness in (among others) petroleum refineries, and information and communication technology goods sectors generally. The US is specialized in office machinery and computers, and aerospace, with relative weakness in textiles, footwear and leather; ferrous metals; and shipbuilding.

2.2 The possible 'inconsistency problem' across industries and countries, and its size

Table 1 is illustrative of the shortcomings of the RCA measure in not reflecting each country's comparative advantage across sectors (Yeats 1985). For example, Austria

[1] A fuller discussion of this topic is present in Sect. 3.

Table 1 Export specialization figures (RSCAs), for 2006 for 27 OECD Countries and the 22 STAN sectors

	AUS	AUT	BEL	CAN	CZE	DNK	FIN	FRA	DEU	GRC	HUN	ISL	IRL	ITA
Food, drink and tobacco	58.6	1.9	13.8	1.1	−30.4	54.7	−52.8	23.0	−15.1	46.8	−12.7	80.6	27.5	0.3
Textiles, footw. and leather	−33.7	8.0	18.5	−46.0	5.1	27.4	−53.7	10.6	−11.0	55.1	−6.2	−78.4	−72.8	55.0
Wood, cork and furniture	24.7	57.5	−4.8	69.4	17.9	14.2	64.7	−20.6	−12.5	−36.8	−11.8	−94.5	−40.9	−33.9
Paper and printing	−32.2	28.6	−12.1	42.0	4.1	−16.3	70.3	−7.0	1.8	−27.0	−33.6	−91.2	−7.5	−15.5
Industrial chemicals	−45.9	−24.3	31.0	−15.8	−36.6	−29.5	−30.1	6.3	−3.4	−16.4	−29.5	−92.5	48.3	−25.7
Pharmaceuticals	−3.7	−3.3	44.5	−47.2	−65.3	29.1	−52.9	10.5	−2.7	16.4	−24.7	−29.7	60.5	−11.1
Petroleum refineries (oil)	18.5	−60.7	19.5	20.0	−57.6	−0.9	15.8	−3.1	−26.0	60.9	−28.4	−19.6	−74.3	−2.3
Rubber and plastics	−45.9	8.2	0.4	6.3	24.4	6.5	−18.7	2.9	8.8	6.5	4.6	−84.0	−55.8	11.7
Stone, clay and glass	−48.4	19.9	5.9	−18.9	40.4	17.6	−5.9	2.1	−1.9	30.0	−3.6	−84.6	−52.9	37.8
Ferrous metals	−44.9	24.3	27.0	−22.1	16.5	−26.4	39.2	7.1	−3.9	15.3	−37.0	−13.9	−93.9	18.2
Non-ferrous metals	82.9	0.5	−7.0	47.4	−52.1	−64.7	18.0	−22.8	−9.6	48.5	−37.1	77.0	−69.3	−23.9
Fabricated metal products	−37.6	29.4	−15.9	−6.4	40.4	12.1	−9.1	−5.5	12.5	6.8	−5.8	−90.7	−59.8	26.6
Non-electrical machinery	−44.2	12.1	−28.2	−23.8	4.6	5.0	1.3	−11.4	13.6	−44.3	−6.3	−63.5	−65.9	28.1
Office mach. and computers	−45.1	−51.9	−41.2	−46.8	36.8	−37.6	−55.1	−35.2	−12.4	−71.6	27.2	−96.1	63.8	−75.2
Electrical machinery	−48.7	11.3	−33.6	−35.2	27.6	15.9	2.0	−3.5	6.3	−9.8	27.6	−96.1	−49.2	−8.3
Communic.eq. and semicon.	−67.5	−22.6	−56.3	−32.9	−11.9	−21.4	37.1	−18.2	−24.4	−48.7	43.0	−97.7	−10.9	−53.8
Shipbuilding	−47.2	−90.1	−92.1	−62.4	−96.0	12.0	36.9	−31.2	−47.9	−49.2	−97.4	−22.8	−96.7	−0.9
Other transport	−43.7	45.3	−15.8	−29.6	20.4	23.2	−71.7	−8.4	−2.1	−77.1	−25.2	−99.6	−91.7	21.5
Motor vehicles	−44.9	1.4	−5.3	24.4	12.8	−64.6	−46.2	−1.0	15.0	−79.0	15.8	−92.9	−96.0	−27.3
Aerospace	−51.4	−58.4	−81.7	12.0	−72.2	−100.0	−91.1	40.9	−1.1	−48.3	−98.2	34.5	−74.7	−53.0
Instruments	−20.3	−31.7	−43.6	−44.1	−48.0	2.7	−25.8	−11.9	−0.6	−63.4	−23.1	−25.4	18.6	−27.8
Other manufacturing	−16.3	10.8	14.5	4.6	19.4	34.3	−57.5	−13.8	−13.7	−39.2	−16.7	−85.7	−59.1	34.6

Table 1 continued

	JPN	KOR	MEX	NLD	NZL	NOR	POL	PRT	ESP	SWE	CHE	GBR	USA
Food, drink and tobacco	−84.6	−74.2	−21.1	36.8	81.0	20.1	21.7	15.7	24.9	−31.4	−31.2	−1.5	−13.2
Textiles, footw. and leather	−55.4	0.9	7.3	−10.3	15.6	−64.5	6.9	62.8	23.9	−34.7	−19.9	−6.8	−29.9
Wood, cork and furniture	−97.3	−96.4	−59.9	−52.5	70.2	1.5	46.9	61.7	−8.8	56.5	−37.8	−63.3	−26.0
Paper and printing	−64.9	−56.5	−47.7	−4.3	14.6	17.4	5.8	14.7	−1.3	53.6	−13.5	1.9	−1.7
Industrial chemicals	−3.6	−0.1	−45.2	19.8	−51.1	7.3	−26.2	−24.4	−7.0	−33.8	4.8	5.8	5.9
Pharmaceuticals	−72.4	−87.8	−74.5	−3.2	−69.2	−34.0	−70.3	−60.7	−6.9	16.8	68.0	25.9	−15.4
Petroleum refineries (oil)	−61.7	26.4	−35.8	47.9	−86.0	67.2	−16.4	16.3	11.8	22.6	−80.1	15.3	−11.1
Rubber and plastics	−1.3	−16.5	−18.5	−13.7	−25.5	−53.3	25.6	16.9	9.8	−10.1	−11.9	−6.6	−4.8
Stone, clay and glass	−5.6	−48.0	3.0	−34.2	−70.9	−33.0	30.2	51.5	39.7	−23.2	−32.2	−10.8	−19.4
Ferrous metals	17.9	17.7	−25.3	−5.2	−38.1	−8.9	−5.8	−11.6	11.0	25.8	−48.8	−10.3	−42.7
Non-ferrous metals	−17.4	−13.4	−19.7	−14.1	27.7	70.2	15.7	−34.6	−8.6	−11.5	−2.4	−8.8	−6.2
Fabricated metal products	−29.1	−16.5	−0.1	−18.9	−25.6	−11.1	37.2	18.8	6.3	6.8	5.2	−5.9	−13.2
Non-electrical machinery	13.5	−21.1	−17.8	−27.9	−35.2	−12.7	−13.6	−29.7	−26.9	5.9	13.5	−6.3	2.0
Office mach. and computers	2.2	18.8	22.6	53.2	−65.8	−61.7	−83.6	−33.8	−69.3	−42.6	−75.7	3.5	16.4
Electrical machinery	10.6	−2.4	43.4	−30.5	−36.1	−30.2	14.8	−6.5	−7.0	−10.5	−0.4	−7.9	0.1
Communic.eq. and semicon.	28.3	46.7	39.2	−4.7	−74.1	−50.3	−20.4	−0.1	−42.9	12.3	−64.8	−11.4	12.3
Shipbuilding	39.8	74.0	−83.3	−45.6	0.4	60.3	51.1	−63.8	44.2	−54.0	−97.6	−48.1	−54.8
Other transport	43.3	−65.5	−14.4	−29.1	−81.3	−58.6	−5.1	−9.3	16.3	−22.8	−17.6	−40.7	−7.9
Motor vehicles	23.2	−4.2	18.8	−54.2	−89.8	−72.8	10.9	−2.9	23.6	0.6	−83.4	−10.0	−14.9
Aerospace	−69.5	−84.5	−74.6	−62.3	−16.1	−31.5	−76.2	−85.6	−30.8	−57.3	−41.7	38.9	46.8
Instruments	13.5	11.2	−1.4	12.0	−48.1	−27.2	−66.5	−66.1	−57.4	−18.6	53.5	2.7	19.4
Other manufacturing	−36.9	−54.0	14.5	−32.9	−42.3	−21.5	45.2	6.4	−15.6	−8.6	32.0	4.6	11.2

Calculations based on OECD27. RSCA figures multiplied by 100 is shown to be specialized in 'wood, cork and furniture' which sector is ranked first among Austria's exports, but among the 27 OECD countries, it is ranked sixth for this sector. Thus, the strength of Austria's comparative advantage in this sector is unclear when using the RCA as the empirical measure. To demonstrate the severity of this problem, Yeats (1985) constructed a correlation between the ranks across sectors and the ranks across 47 countries, based on 1976–1978 aggregate trade data. His criticism of this index was based on his finding of only 60 % of cases with significant correlation coefficients (5 %) between the two. In order to test Yeats's results we conducted a similar analysis of observations for every year between 1987 and 2006, for 22 sectors and 22 of the 27 OECD countries in Table 1 (ranked within each year).[2]

While it is true that large country size differences can be the cause of such problems, when in applying the RCA across countries, it seems likely that Yeats's results overestimated the 'inconsistency problem' (at least when more developed countries are compared); we found less than 1 % insignificant rank correlations (1 % level) for the 22 countries for the 20 years (440 correlations) in our dataset (across the 22 sectors in each case). None of the rank correlations were insignificant at the 5 % level. The average of the Spearman correlations across the 440 correlations was 0.84. For the pooled data (9,680 observations), we found a (highly significant) rank correlation coefficient of 0.78.

3 Symmetric RCA

3.1 Why the asymmetry of the RCA is a problem

In Sect. 2 the RCA index was made symmetric, although the rationale for following this procedure was not explained in detail. In this section, we argue that the index should always be made symmetric for econometric analysis applications,[3] because the 'pure' RCA is not comparable on both sides of unity: the index ranges from zero to 1 if a country is categorized as not specialized in a given sector, and ranges from 1 to infinity if a country is specialized. This implies that using the non-adjusted RCA in regression analysis (or other statistical analysis) gives much more weight to values above 1 compared to observations below 1.

The problem can be illustrated by an example (see Table 2). For instance, if a country increases its RCA value from 0.5 to 1, between two periods, specialization in this sector has increased by a factor of 2. Similarly, if the RCA value increases from 1 to 2, specialization has increased by a factor of 2. However, the respective absolute differences are 0.5 and 1. Table 2 presents the problem in the context of

[2] In the remainder of the paper we work with 22 countries since we do not have complete data for the Czech Republic, Hungary, Korea, Mexico and Poland for the entire time-period.

[3] Another and very similar measure to the RSCA has been applied by Hariolf Grupp in various publications (see e.g., Grupp 1994, 1998) in the context of technological specialization. *RPA* or Revealed Patent Advantage can be defined as:

$RPA_{ij} = (RTA^2 - 1)/(RTA^2 + 1) \times 100$, where *RTA* is Revealed Technological Advantage, calculated similar to RCA (see Eq. 1) but based on US patent data.

Table 2 An example of the effect of RCA vs. RSCA

	RCA_{t-1}	RCA_t	$RSCA_{t-1}$	$RSCA_t$	Specialization/de-spec.
Automobiles	8	4	7/9	0.6	D
Aeroplanes	1/4	1/8	−0.6	−7/9	S
Computers	1	2	0	1/3	S
Chemicals	1/2	1	1/3	0	D
Result for all sectors	De-specialization		Neutral		

increased or decreased level of specialization, between two periods ($t - 1$ and t). In the example, specialization has gone up or down by exactly the same percentages, on both sides of unity. However, since the changes in RCA above 1 are numerically much larger than the values below 1, the conclusion based on the (unadjusted) Balassa indices is that the country has de-specialized when in reality it has remained neutral. Another way of expressing the problem in the context of regression analysis, is that one of the disadvantages of the Balassa measure is the inherent risk of lack of normality in its distribution because it takes values between zero and infinity with a (weighted) average of 1.0. A skewed distribution is likely to violate the assumption of normality of the error term in regression analysis and to produce unreliable t-statistics.

3.2 Empirical illustration of the problem: are specialization patterns stable over time?

Vollrath (1991) suggests the logarithm of RCA as the solution to the asymmetry problem of the RCA index. While this approach is helpful, the adjusted index is not defined in the case of a country with zero exports in a sector. As previously suggested, we recommend using a symmetric version of the RCA, obtained as (RCA − 1)/(RCA + 1), which we call RSCA. This index has similar properties to the logarithm solution but can be defined in the case of zero exports from a sector.

In this section, we illustrate the asymmetry problem empirically by comparing the results from applying RCA and RSCA. We discuss and analyze the problem in the context of whether countries tend to decrease or increase the level of specialization, and from the perspective of accessing the degree to which trade specialization patterns are stable over time (or not). As hinted in the introduction, although we use these contexts to illustrate the biases involved, the asymmetry problem is equally important for all econometric analysis contexts that apply RCA (or some version of it).

Regarding the degree to which trade specialization patterns are stable over time, evolutionary economics assumes that technology is an important determinant of international specialization (see also, Dalum et al. 1998). Provided that technologies are relatively stable across time and space, the strong link between technological and trade specialization will lead to trade specialization patterns that are stable over time

(Dosi et al. 1990). Important aspects of technology are mainly specific and tacit in nature, since to a large extent, the technology is embodied in persons and institutions as well as being cumulative over time (Dosi et al. 1990; Dosi and Nelson 2013). Given this set of assumptions, firms produce things that are technically different from things that other firms produce, on the basis of in-house technology but with contributions from other firms and from public institutions and public knowledge (Dosi et al. 1990). Accordingly, firms are unlikely to improve their technology by conducting a survey of the complete stock of knowledge before making their technical choices. Rather, given the differentiated nature of technology, firms will try to improve and diversify their technology by searching in zones that enable them to build on their existing technology base. Thus, technological and organizational change is a cumulative process which works to constrain the possibilities for what firms can do on the basis of what they have done in the past (i.e., path dependency). In this perception of technology, its development over time ceases to be random and is constrained by the set of existing activities (Dosi et al. 1990: 8). Thus, if trade specialization is related closely to technological specialization at country level (Soete 1981, 1987; Laursen 2000b) specialization patterns can be expected to remain stable at the national level over very long time periods.

Krugman (1987) adopts a different theoretical perspective and proposes a model that predicts a stable pattern of country specialization based on the presence of economies of scale. In this model, the productivity of a country's sectors based on available resources depends on accumulated experience ('learning-by-doing') which creates economies of scale at the industry level. Thus, in this model, once a pattern of specialization is established (perhaps by chance), it remains unchanged; changes in relative productivity act to further lock in this specialization pattern. In sum, regardless of the approach, theory suggests a strong degree of persistence of international trade specialization patterns over time.

The methodology used to examine the stability of trade patterns is briefly outlined here; for further details the reader can consult Dalum et al. (1998) (or Cantwell 1989). Stability (and specialization trends) is tested using the following regression equation (country by country):

$$RSCA_{ij}^{t_2} = \alpha_i + \beta_i RSCA_{ij}^{t_1} + \epsilon_{ij} \tag{2}$$

The superscripts t_1 and t_2 refer to the initial and final years, respectively. The dependent variable, RSCA at time t_2 for sector i, is tested against the independent variable which is the value of the RSCA in the previous year t_1. α and β are standard linear regression parameters and ε is a residual term. Basically, the size of β^* measures the stability of a country's specialization pattern between the two periods. A low β^* indicates a high degree of turbulence but if β^* is not significantly different from 1 then the pattern has remained unchanged, β^*/R^* (R^* is the regression correlation coefficient) measures whether the level of specialization has gone up or down between the two periods (an increase or a fall in the spread of specialization). If $\beta^*/R^* > 1$, specialization has increased; if $\beta^*/R^* < 1$ then specialization has decreased.

If the non-adjusted RCA is used to estimate Eq. 2, the estimates might be biased (an example of an application of a non-adjusted RCA includes Crafts and Thomas

1986). Table 3 presents the results of the estimations based on Eq. 2 using the original Balassa figures, and using the RSCA. The results show that (at least in this case) the reduction in specialization between 1987 and 2006 is slightly higher using the unadjusted RCA compared to the RSCA (β*/R* of 0.89 and 0.94, respectively). Table 3 also presents the results for the Jarque–Bera test for normality of the error terms. The hypothesis of normality of the error terms can be rejected for 12 out of 22 regressions (10 % level) when using the adjusted RCA, and for 17 out 22 regressions when the standard Balassa figures are applied. We noted earlier that the index should be adjusted for theoretical reasons; the present analysis suggests that not only does the adjustment matter for the empirical results but after adjustment, the problems related to lack of normality of the error terms in the regression analysis are less severe.

Table 3 Differences between increased or decreased specialization, using RCA and RSCA respectively, 1987–2006 ($n = 22$ sectors)

	RCA				RSCA			
	β*	S.E.	β*/R*	Jarque–Bera test (*p* value)	β*	S.E.	β*/R*	Jarque–Bera test (*p* value)
Australia	0.71[a,b]	(0.02)	0.72	0.04	0.73[a,b]	(0.07)	0.79	0.24
Austria	0.75[a,b]	(0.12)	0.92	0.00	0.75[a,b]	(0.09)	0.85	0.01
Belgium	0.80[a]	(0.15)	1.05	0.00	0.87[a]	(0.11)	1.00	0.02
Canada	0.82[a,b]	(0.05)	0.85	0.58	0.77[a,b]	(0.08)	0.84	0.07
Denmark	0.73[a,b]	(0.08)	0.81	0.11	0.90[a]	(0.08)	0.97	0.19
Finland	0.67[a,b]	(0.07)	0.74	0.01	0.89[a]	(0.16)	1.14	0.02
France	0.72[a]	(0.21)	1.17	0.00	0.67[a,b]	(0.16)	0.98	0.04
Germany	0.64[a,b]	(0.09)	0.75	0.11	0.55[a,b]	(0.08)	0.66	0.09
Greece	0.60[a,b]	(0.08)	0.71	0.00	0.76[a,b]	(0.06)	0.81	0.83
Iceland	0.91[a]	(0.08)	0.98	0.00	0.85[a]	(0.14)	1.05	0.15
Ireland	0.90[a]	(0.16)	1.14	0.05	0.94[a]	(0.15)	1.15	0.38
Italy	0.92[a]	(0.09)	1.00	0.02	0.84[a]	(0.15)	1.08	0.03
Japan	0.87[a]	(0.10)	0.98	0.00	0.93[a]	(0.07)	0.99	0.58
Netherlands	0.65[a,b]	(0.16)	0.98	0.00	0.84[a]	(0.16)	1.09	0.00
New Zealand	1.18[a,b]	(0.09)	1.25	0.04	0.77[a,b]	(0.11)	0.91	0.05
Norway	0.51[a,b]	(0.08)	0.61	0.00	0.91[a]	(0.08)	0.98	0.88
Portugal	0.63[a,b]	(0.06)	0.68	0.05	0.74[a,b]	(0.11)	0.90	0.20
Spain	0.61[a]	(0.24)	1.24	0.00	0.71[a,b]	(0.15)	0.99	0.05
Sweden	0.78[a,b]	(0.06)	0.82	0.07	0.89[a]	(0.11)	1.02	0.08
Switzerland	0.93[a,b]	(0.04)	0.94	0.49	0.92[a,b]	(0.04)	0.94	0.15
United Kingdom	0.22[b]	(0.13)	0.64	0.09	0.49[a,b]	(0.14)	0.81	0.00
United States	0.57[a,b]	(0.06)	0.63	0.79	0.64[a,b]	(0.08)	0.74	0.19
Mean	0.77		0.89		0.79		0.94	

Calculations based on OECD22

[a] Denotes significantly different from zero at the 10 % level

[b] Denotes significantly different from unity at the 10 % level

4 RCA and the alternatives

Although widely used, RCA is not the only measure of international trade specialization. Other measures include the Michaely index, Contribution to the Trade Balance, the Chi Square measure and Bowen's (1983) Net Trade Index (NTI). The NTI has been criticized on a number of counts including the underlying assumption of identical and homothetic preferences across countries (see Ballance et al. 1985); for this reason we do consider this measure further. However, we define the remaining alternative measures and compare each individual measure to the RSCA. The Michaely index can be defined as:

$$MI_{ij} = \frac{X_{ij}}{\sum_i X_{ij}} - \frac{M_{ij}}{\sum_i M_{ij}} \times 100, \tag{3}$$

where X_{ij} are sector i's exports by country j, and M_{ij} are sector i's imports by country j. The first part of the formula (before the minus sign) represents the percentage share of a given sector in national exports, the second part represents the percentage share of a given sector in national imports. The measure ranges between [−100; 100], with a neutral value of zero. If the value of the index is positive then the country is specialized in some sector, while a negative value indicates under-specialization. This indicator was developed by Michael Michaely (1962/67), as a national 'index of dissimilarity'. In the original contribution, Michaely sums the sectors of each country so that the higher the value of the index, the less similar is the commodity (sectoral) composition of the country's exports and imports. The index takes the value zero in the case of perfect 'similarity'. Since Michaely's original contribution, several studies of international trade (e.g. Kol and Mennes 1985; Webster and Gilroy 1995), have applied this index to measure trade specialization at the sector level.

A very similar measure—the Contribution to the Trade Balance (CTB)—was proposed by CEPII (1983), and can be defined as:

$$CTB_{ij} = \frac{X_{ij} - M_{ij}}{\left(\sum_i X_{ij} + \sum_i M_{ij}\right)/2} \times 100 - \frac{\sum_i X_{ij} + \sum_i M_{ij}}{\left(\sum_i X_{ij} + \sum_i M_{ij}\right)/2} \times \frac{X_{ij} + M_{ij}}{\sum_i X_{ij} + \sum_i M_{ij}} \times 100, \tag{4}$$

The letters and subscripts denote the same as in Eq. 3. The measure ranges between [−400; 400]. Values of the *CTB* index greater than zero (less than zero) identify those sectors making a higher (lower) contribution than their percentage share in the country's total trade. This measure is applied in Amendola et al. (1992), Amable (2000), and Guerrieri (1997). In the present paper, because of the similarity between the CTB and Michaely measures, including their pros and cons, we compare the Michaely and the RSCA indices. The two measures (the CTB and Michaely indices) differ only if there are very large trade imbalances in a given country. In the real world, the two measures are virtually identical: using our sample, in correlations between the two measures across 20 years and 22 sectors

Table 4 An example of differences between indices of specialization: Denmark 2006

	RSCA	Michaely index	χ^2
Food, drink and tobacco	53.8	9.9	33.6
Textiles, footwear and leather	22.6	−1.6	1.4
Wood, cork and furniture	13.9	−1.1	0.1
Paper and printing	−19.8	−1.6	0.4
Industrial chemicals	−30.8	−2.1	2.3
Pharmaceuticals	27.1	5.1	2.8
Petroleum refineries (oil)	−7.1	−0.6	0.0
Rubber and plastics	7.8	0.1	0.1
Stone, clay and glass	−1.6	−0.4	0.0
Ferrous metals	−32.1	−2.7	0.7
Non-ferrous metals	−55.4	−0.9	1.2
Fabricated metal products	15.1	−0.1	0.3
Non-electrical machinery	6.0	3.1	0.2
Office mach. and computers	−29.0	−3.2	0.8
Electrical machinery	13.7	1.9	0.4
Communic. eq. and semiconductors	−19.0	−1.6	0.7
Shipbuilding	27.3	−0.9	0.4
Other transport	28.2	−1.5	0.4
Motor vehicles	−64.2	−5.2	9.2
Aerospace	−100.0	0.0	3.3
Instruments	−0.5	1.9	0.0
Other manufacturing	32.8	1.7	2.4

Calculations based on OECD22. RSCA figures multiplied by 100

(440 observations), for the each of the 22 countries, all countries displayed correlation coefficients of around 0.99.

Compared to the RSCA, the Michaely index measures relative net exports in a given sector. However, when comparing the RSCA and the Michaely index, the type and size of intra industry-trade becomes important. One advantage of the Michaely index is that it eliminates distortion due to re-exports when calculating comparative advantage. However, when intra-industry trade occurs because firms in other sectors purchase equipment both domestically and via imports, the Michaely index underestimates the comparative advantage of a country in a given sector. An example of this is presented in Table 4 in the case of Danish specialization in shipbuilding in 2006. It can be seen that the RSCA value suggests rather strong specialization in this sector, while the Michaely suggests slight under-specialization in this sector. This is because Denmark has a strong downstream shipping sector, not only buying ships from domestic shipyards, but also importing a substantial amount of ships, thereby strongly reducing the value of the Michaely index. So in this case, we would argue that RSCA is a better measure of comparative advantage. In general, it would seem reasonable to argue that the benefits from avoiding problems related to re-exports are smaller than the (to some extent arbitrary)[4] demand from other related sectors in the economy. Another reason for preferring RSCA over the Michaely index is that RSCA can be applied to patent data (see e.g., Soete 1987) as well as production or investment data while the Michaely index can be used only in relation to trade data.

Definition of the χ^2 measure can be set up as follows:

$$\chi_j^2 = \left\langle \left[\frac{X_{ij}}{\sum_i X_{ij}} - \frac{\sum_j X_{ij}}{\sum_i \sum_j X_{ij}} \right]^2 \Big/ \frac{\sum_j X_{ij}}{\sum_i \sum_j X_{ij}} \right\rangle \times 100, \qquad (5)$$

where the letters and subscripts denote the same as in the definition of the RCA, in Eq. 1. χ^2 measures the squared difference between the export distribution of a given country and the total OECD divided by the OECD export distribution. The size of χ^2 is an indication of the strength of each country's specialization. The more a country differs from the OECD average, the higher this value. In the original formulation, Archibugi and Pianta (1992) sum the sectors (i), in order to arrive at one number for each country such that if a country has an export structure (patent structure in their case) exactly similar to the OECD average, the value of the indicator will be zero. However, since we want to compare directly with RSCA, we do not sum the sectors. This does not change the basic properties of the measure. However, there is a very important difference between the Chi Square measure and the RSCA; the Chi Square measures only the level of specialization. It takes high values if a country is seen to be (much) less specialized than the average for the countries being analyzed, and if the country is (much) more specialized in a sector (commodity group) compared to the average for the countries. The measure ranges between [0; ∞[, although the index takes the value zero only if there is just one country in the world producing everything. One disadvantage of the measure is—similar to the unadjusted RCA index—the asymmetric nature of the measure around its neutral value. However, this problem could perhaps be overcome by an adjustment of the measure, similar to the one implied by the application of the RSCA rather than the RCA index. More importantly, compared to the RSCA, the Chi index suffers from the disadvantage that it results in very large values if one sector accounts for a large percentage of total exports. An example of this is presented in Table 4 which shows a Chi Square value of 33.3 for Denmark's exports of food, drink and tobacco with the next highest value only 9.2 for exports of motor vehicles indicating Denmark's under-specialization in this sector. This is a difference by a factor 3.6; the difference between the highest and second highest values according to the RSCA and Michaely indices is around a factor of 2 in both cases. Food, drink and tobacco accounts for 19 percent of Danish exports in 2006 compared to e.g. Danish specialization in non-electrical machinery which accounted for around 13 percent of total Danish exports in 2006 and has a Chi Square value of 0.2. This difference is of a factor of 167 according to Chi Square, while the difference using RSCA is a factor of 9. One of

[4] It can be argued that e.g. the relative strength of the Danish shipyards is, at least partially, due to the strength of the shipping industry (and perhaps vice versa) (see, Linder 1961; Andersen et al. 1981; Fagerberg 1995). However, it would be difficult to argue that Denmark has no comparative advantage in building ships and boats given the high level of exports from this sector.

Table 5 Correlations between the RSCA index and two other indexes of international trade specialization; yearly observations 1987–2006, across 22 sectors ($n = 440$)

	Michaely index	χ^2	Adjusted χ^2
Australia	0.83[a]	0.61[a]	0.64[a]
Austria	0.58[a]	0.20[a]	0.81[a]
Belgium	0.44[a]	0.09	0.73[a]
Canada	0.82[a]	0.67[a]	0.80[a]
Denmark	0.57[a]	0.27[a]	0.52[a]
Finland	0.68[a]	0.48[a]	0.55[a]
France	0.58[a]	0.40[a]	0.76[a]
Germany	0.57[a]	0.03	0.73[a]
Greece	0.76[a]	0.47[a]	0.59[a]
Iceland	0.71[a]	0.61[a]	0.63[a]
Ireland	0.68[a]	0.56[a]	0.71[a]
Italy	0.71[a]	0.48[a]	0.66[a]
Japan	0.67[a]	0.13[a]	0.70[a]
Netherlands	0.65[a]	0.59[a]	0.81[a]
New Zealand	0.67[a]	0.50[a]	0.54[a]
Norway	0.75[a]	0.63[a]	0.71[a]
Portugal	0.65[a]	0.45[a]	0.51[a]
Spain	0.69[a]	0.15[a]	0.70[a]
Sweden	0.78[a]	0.47[a]	0.69[a]
Switzerland	0.69[a]	0.45[a]	0.69[a]
United Kingdom	0.43[a]	0.31[a]	0.65[a]
United States	0.52[a]	0.46[a]	0.69[a]

Calculations based on OECD22

[a] Denotes different from zero at the 1 % level

the implications of the χ^2 measure bias is that the index is also very sensitive to changes in the size of large sectors over time.

Table 5 presents the correlations between the RSCA index and the other two central measures discussed in this paper, for each country in the STAN database, across 22 sectors and over 20 years. The last column of Table 5 shows an adjusted χ^2 measure allowing the index to be compared directly to the other measures;[5] the numerator is multiplied by -1 if the 'non-squared' numerator is smaller than zero. More generally, when looking at measures for the direction of specialization, Table 5 shows that despite the differences between the different measures of international specialization highlighted above, the measures are quite strongly correlated for all the 22 countries. In this context, note that the correlations between the RSCA and the Chi Square measures are to an extent expected since the definitions of these two measures use different combinations of the same basic components.

As already mentioned, the Chi Square measure is used in the literature to measure specialization levels (and changes in levels); the other two measures also capture the direction of specialization. However, we show in Sect. 3 that RSCA can also be

[5] The problem—as mentioned earlier—is that the χ^2 measure takes high values both if a country is (much) more specialized in a sector, and if a country is (much) less specialized in a sector.

used to measure changes in the level of specialization. So do the RSCA regressions and the χ^2 measure point in generally the same direction for increased or a decreased level of specialization? In order to investigate this question, we analyzed the 22 countries and 6 time periods[6] to check whether specialization went up or down year to year, using both types of indices (126 cases in total, based on 6 periods and 22 countries) across the 22 sectors. Recall that the condition for increased specialization in the case of RSCA is $\beta^*/R^* > 1$ ($\beta^*/R^* < 1$ for de-specialization) and for the (original country-level or 'unadjusted') χ^2 measure is $\chi^2_{t_2}/\chi^2_{t_1} > 1 (\chi^2_{t_2}/\chi^2_{t_1} < 1$ for de-specialization). The results of correlation analysis show a highly significant σ, although the value of σ is only 0.34. In 68 percent of cases, both indicators point in the same direction; in 32 % of cases they point in opposite directions. Thus, in the majority of (but not all) cases the two measures point in the same direction for increased or decreased level of specialization. Both indicators show that international trade specialization appears to increase in about 40 percent of the country-time period cases and decrease in the remaining 60 % of cases.

5 Conclusion

The aim of this paper was to study the effects of the asymmetry of the Balassa index around its neutral value, and to show how this measure compares with other measures of international specialization from both a theoretical and empirical point of view. In Sect. 2, we briefly described those countries that are specialized according to the RSCA index, explored criticisms of this measure for not adequately reflecting comparative advantage consistently for each country, across sectors (Yeats 1985). From a theoretical point of view, comparative advantage is an unambiguous concept. Consistent with Yeats (1985), we show that the RCA (or RSCA) does not necessarily compare sectors of equal rank within the same country and across different countries. We concluded that although large differences in country sizes can cause such inconsistency problems, when applying RCA across countries, it seems likely that Yeats's results overestimate the 'inconsistency problem' if we consider a much larger sample of country-year observations.

In Sect. 3, we demonstrated that when using the RCA, it should always (at least in statistical analysis) be adjusted so that it becomes symmetric around its neutral value. This conclusion is based on a theoretical discussion of the properties of the measure and on empirical evidence from the Jarque–Bera test for normality of the error terms in regressions comparing RCA and RSCA. These findings have implications for any study that utilizes RCA for statistical analysis, regardless of whether the underlying data are on exports, production, or patents. In particular, our conclusion regarding the asymmetry of the RCA, implies that the results from studies that apply 'raw' or unadjusted RCA (such as, for instance, Crafts and Thomas 1986; Amiti 1999; Hidalgo et al. 2007; Hausmann and Hidalgo 2011) may be inaccurate due to the asymmetry of the RCA around its neutral value. It should be

[6] The years: 1988–1991; 1991–1994; 1994–1997; 1997–2000; 2000–2003; and 2003–2006.

noted, however, that it is beyond the scope of this paper to argue about the severity of the problem in the particular studies cited above.

In Sect. 4, we compared RSCA to other measures of international trade specialization used in the literature such as the Michaely index, the Contribution to the Trade Balance, the Chi Square measure, and the Net Trade Index. We discarded the NTI for theoretical reasons, and also did not investigate the CTB since we found it to be nearly identical to the Michaely index. Based on a comparison between the Michaely index and the Chi Square measure, and the RSCA index we found that the last is the best measure of comparative advantage, although all three measures have pros and cons. Our findings are based on the observation that RSCA better reflects the concept of specialization through its focus on a narrower area of economic activity within a given country, and less deep examination of other areas of activity. The Michaely index (and the CTB measure) involves deducting foreign demand for a good from a certain sector, thereby reducing the level of economic activity—as reflected by the index—in that sector of the economy. The need for import data to calculate the index also limits the possibility their use in the context of other variables such as patents or production statistics. The Chi Square indicator only measures the level of specialization, regardless of whether a country is specialized or under-specialized in a certain sector. In addition, the way that the measure is calculated gives rise to rather strong fluctuations over time. Nevertheless, when applied on the same data the three measures are quite strongly correlated. It is hoped that the analysis in this paper will inform future studies of the dynamics of international specialization.

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